TECHNICAL ANALYSIS USED TO DEVELOP OPTIONAL NONATTAINMENT BOUNDARIES FOR 8-HOUR OZONE FOR THE GREATER PHOENIX AREA

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Prepared For

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Introduction

Ozone concentrations in the Greater Phoenix Area exceed the U.S. Environmental Protection Agency (EPA) 8-hour ozone standard of 0.08 parts per million (ppm), or an equivalent value of 80 parts per billion (ppb). Due to rounding conventions, a concentration of 85 ppb or higher exceeds the standard. Compliance with the standard is based on three-year averages of the fourth highest value for each year, at each monitor. Ozone concentrations in areas influenced by emissions in the Phoenix area have exceeded the standard for each three-year period since the standard was proposed by EPA in 1997. Maximum values have been in the range of 85 to 88 ppb.

The methods used to develop the optional nonattainment area boundaries for 8-hour ozone described in this report use information covering each of the eleven designation criteria in EPA Guidance on establishing boundaries for the 8-hour standard, dated March 28, 2000. The actual technical approach directly follows the requirements in Section 107 (d) (1) of the Clean Air Act Amendments which, "requires all areas to be designated non-attainment if they do not meet the standard or contribute to ambient air quality in a nearby area that does not meet the standard."

Per the requirement quoted above, the nonattainment boundary options were developed by separate analyses to map the areas of ozone impact where the standard is exceeded, and a separate but closely-related analysis, to determine the geographic area where pollutant emissions contribute to the ozone concentrations above the standard. The area where ozone exceeds the ambient standard is referred to in this report as the "Receptor Area", and the area where emissions occur which contribute to ozone violations is referred to as the "Source Area."

Two alternative design criteria were used to produce the optional boundaries. One design criterion is an 85 ppb, three-year average of the fourth high value, which is the effective level of the standard. Under this criterion, the boundary was constrained to enclose the geographic area where there is high confidence that the standard is exceeded. The other design criterion value is 80 ppb.

The boundary developed using the 80-ppb criterion is a larger area because it includes the entire 85-ppb area as well as additional areas where concentrations are generally in the 80-85 ppb range, but without any measurements indicating ozone levels above the standard.

Receptor Area Analysis

An attempt was made to use all available information relevant to determine the geographic extent of ozone violations in the vicinity of the Phoenix area under current emissions. The three basic information tools: ozone monitoring data, ozone simulation modeling, and wind measurement analysis, were used in this evaluation. These tools and their specific roles in the development of the boundary options are described below.

Ozone Monitoring

Maricopa County, Pinal County, and ADEQ, operate an extensive network of ozone monitors in and around the Greater Phoenix Area. Currently there are 26 monitors in operation, mostly in the urbanized area, but a significant number are located in rural and even remote locations as far as 80 miles from central Phoenix.

A concern with using historical ozone measurement records for the purpose of designating a nonattainment area occurs when there is any evident trend in the data. Over time, ozone concentrations have decreased in the Phoenix area, as is evident by the attainment of the 1-hour standard in 1997. The measurement record of 8-hour ozone concentrations from 1995 through 2002 was evaluated for possible use in this project. It was concluded that ozone concentrations decreased through 1996 but that no apparent trend has occurred since then.

Table 1 shows the fourth highest ozone concentrations for the ozone monitoring network for the period 1995 through 2002. The last row on this table shows the average concentration for the network by year. These averages reveal a drop in concentration levels after 1996, with stable values thereafter. Average values for a subset of the network comprised of ten monitors that were in operation for all eight years reveals the same pattern of stable concentrations from 1997 through 2002, see Table 2. Therefore, the 1997 through 2002 portion of the historical record was used in the development of the boundary options and is considered representative of current conditions.

All ozone ambient measurements available for the 1997through 2002 time period were used in this evaluation including data from discontinued monitors, those with fewer than three years of data, and new monitors. The monitoring record and judgments regarding the spatial representation of each monitor were the principle tools used in developing the boundary options.

Table 1. Annual Fourth Highest 8-Hour Ozone Concentrations, 1995 – 2002

Annual Fourth Highest 8-Hour Ozone Concentration in Parts per Billion (PPB)									
Monitor Site	**Abbreviation**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**
Gila County									
Rye	RY			56	65	80			
Tonto N.M.	TONO								**87**
Maricopa County									
Blue Point	BP			83	**89**	**87**	**87**	80	**86**
Cave Creek	CC							83	**86**
Central Phoenix	CP	**85**	76	77	79	78	76	75	76
Emergency Management	EM			**85**	81	**86**	70	63	
Falcon Field	FF			81	83	82	75	81	84
Fountain Hills	FH			**88**	**86**	**86**	**85**	83	**86**
Glendale	GL	80	72	76	70	81	81	78	83
Humboldt Mountain	HM			81	**90**	**86**	82	**85**	**90**
Lake Pleasant	LP				82	81	82	73	
Maryvale	MA			78	**86**	77	80	73	84
Mesa	ME	**92**	**90**	84	80	83	75	74	72
Mt. Ord	MO			84	**88**	**87**	**90**	77	
North Phoenix	NP	**92**	**95**	**91**	**89**	84	**86**	**86**	**85**
Palo Verde	PAVE		71	77	80	80	80	74	78
Pinnacle Peak	PP	**91**	**91**	82	**86**	83	**86**	**85**	84
Rio Verde	RV			**85**	79	**86**	**86**	83	**85**
Roosevelt	RO			84					
Salt River Pima	SRPI	**92**	**92**	82	**87**	82			
South Phoenix	SP	84	**91**	75	80	75	83	76	81
South Scottsdale	SS	**89**	**87**	76	78	72	80	79	77
Super Site	PXSS		**87**	79	79		76	79	76
Surprise	SU							71	79
Tempe	TE						78	79	80
Vehicle Emissions	VE	**92**	80						
West Chandler	WC			77	74	69	74	78	83
West Phoenix	WP	84	81	78	**86**	**91**	81	75	84
Pinal County									
Apache Junction	AJ	**91**	**85**	82	82	80	82	78	80
Casa Grande	CG	71	79	72	68	78	75	74	78
Queen Valley	QUAZ							79	83
Yavapai County									
Hillside	HISD		**85**	76	83	84	83	76	**89**
Gila, Maricopa, Pinal, and Yavapai Counties									
Average All Monitors		87	84	80	81	82	81	78	82

Table 2. Annual Fourth Highest 8-Hour Ozone Concentrations for Monitors in Operation, 1995 - 2002

Annual Fourth Highest 8-Hour Ozone Concentration in Parts per Billion (PPB) – for monitors in operation 1995 through 2002									
Monitor Site	**Abbreviation**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**
Maricopa County									
Central Phoenix	CP	**85**	76	77	79	78	76	75	76
Glendale	GL	80	72	76	70	81	81	78	83
Mesa	ME	**92**	**90**	84	80	83	75	74	72
North Phoenix	NP	**92**	**95**	**91**	**89**	84	**86**	**86**	**85**
Pinnacle Peak	PP	**91**	**91**	82	**86**	83	**86**	**85**	84
South Phoenix	SP	84	**91**	75	80	75	83	76	81
South Scottsdale	SS	**89**	**87**	76	78	72	80	79	77
West Phoenix	WP	84	81	78	**86**	**91**	81	75	84
Pinal County									
Apache Junction	AJ	**91**	**85**	82	82	80	82	78	80
Casa Grande	CG	71	79	72	68	78	75	74	78
Maricopa and Pinal Counties									
Average All Monitors		86	85	79	80	81	81	78	80

Exceedances of the 8-hour ozone standard are represented in blue.

The density and distribution of ozone monitors in the urbanized area is adequate to define the portions of the urbanized area that exceed either the 80- or 85-ppb design criteria. However, in rural areas there are relatively large distances between monitors. The extensive areas with mountainous and complex terrain complicate the interpretation of the measurement data and require the consideration of such phenomena as plume impingement on high terrain, and ozone shadows on the leeward side of mountains. Furthermore, some of the highest concentrations of ozone have been measured at the periphery of the monitoring network, which begs the question as to the extent of ozone at levels that exceed the standard beyond these monitor locations.

The first step in attempting to fill the gaps between and beyond the rural monitors is to determine the spatial representation of each monitor. This was accomplished by a careful review of the measurements record of each monitor and comparisons between measurements at different sites. This evaluation was done in the consideration of topographic influences, airflow patterns, and ozone formation dynamics.

The results of the dispersion modeling and an analyses of wind conditions during the two ozone episode periods in 2002 were used in this exercise to interpret the ambient ozone data record.

Modeling

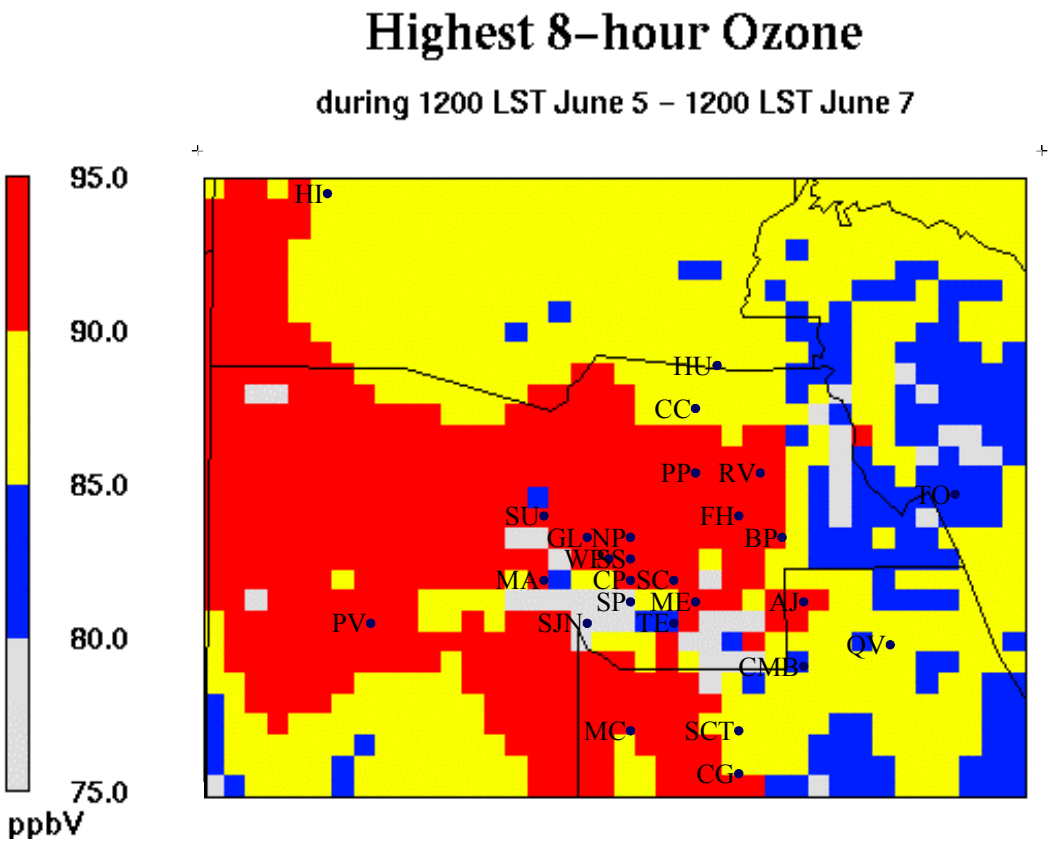
ADEQ contracted with the Arizona State University's, Environmental Fluid Dynamics Program to perform ozone modeling for two episode periods in 2002, June 4 through 7 and July 9 through 13. Emissions inventories for the two episodes were developed by Dr. Susanne Grossman-Clark, using the EPA approved SMOKE model for anthropogenic and biogenic emissions of nitrogen oxides (NOx) and volatile organic compounds (VOC's). Ozone dispersion modeling was performed by Dr.Sang-Mi Lee and Dr. S. Fernando. The ozone modeling employed EPA approved models. The MM5 model was used for the meteorological modeling which was input to the CMAQ model for ozone simulations.

Both the MM5 and CMAQ modeling results were validated by comparison with measured meteorological and ozone data, and were found to exceed EPA criteria for acceptable model performance. Although the models performed well, the winds predicted by MM5 tended to be late on the timing of the daily wind shift from nighttime drainage winds, generally from the east, to upslope flow, generally from the southwest. Unfortunately, this shift actually occurs within a few hours after sunrise at the beginning of the daily ozone production period. The effect is modeled over-predictions of the geographic extent and concentrations of ozone to the west of the urbanized area and a delay in transport to the northeast resulting in under-predictions of ozone to the northeast.

The modeling results were not used to explicitly to determine the non-attainment boundaries but rather provided a theoretical input, not otherwise available, as to the potential extent of high 8-hour ozone downwind of the Greater Phoenix Area. The

modeling indicates the potential for 8-hour ozone concentrations above 85 ppb at distances greater than 80 miles from central Phoenix, as can be seen on Figure 1, which shows the modeling results for June 6, 2002. This potential is considered in the interpretation of monitored ozone concentrations in light of actual wind persistence from a given direction in estimating the downwind extent of the non-attainment area.

Figure 1. Highest 8-Hour Ozone Concentrations: 1200 LST June 5 through 7, 2002

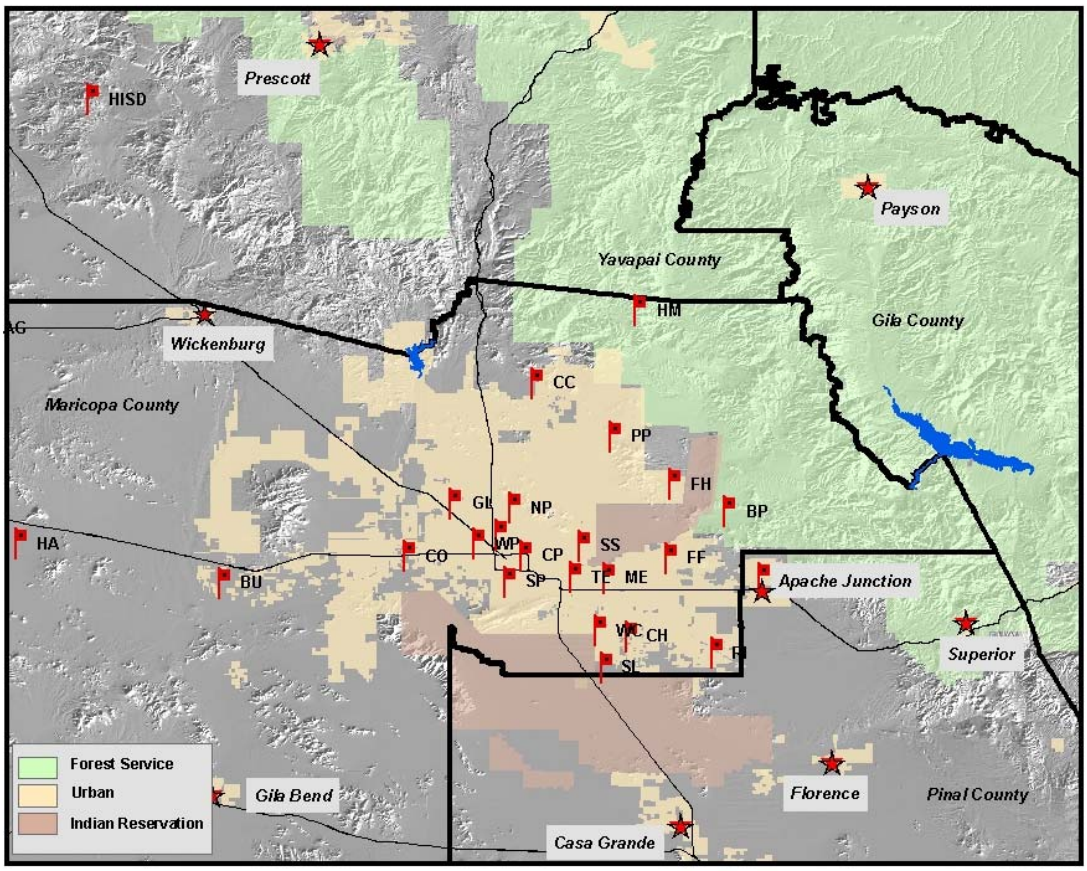


Source: ASU Mechanical and Aerospace Engineering Department

Wind Analysis

ADEQ provided hourly records of wind direction and speed from instruments operated by Maricopa County, Salt River Project, University of Arizona, and ADEQ for the nine days of the two ozone episode periods in 2002 which had ozone concentrations higher than 85 ppb. The wind data were used to characterize general airflow patterns and their variations on the nine days with 8-hour ozone values exceeding the standard. The location of the wind sites are shown on Figure 2.

Figure 2. Wind Monitoring Sites



Sources: University of Arizona, Salt River Project (SRP), Maricopa County, Arizona Department of Environmental Quality (ADEQ), U.S. Geological Survey (USGS), ALRIS

Each episode day exhibited the same general pattern and consequent ozone transport. Downslope or drainage winds, generally from the east, usually persisted till a few hours after sunrise which is typical during the summer ozone season. The transition from drainage to upslope typically lasts for two to three hours, but during the nine days studied the transition varied from one to eight hours. The transitional period corresponds with the beginning of the daily photochemical ozone formation period. During the transition, winds rotate in a clockwise fashion through south before completing the shift to blowing from the southwest quadrant which is typical upslope flow for this area. Upslope winds generally begin about noon and last till near sunset. During the nine days studied upslope flow varied from six to twelve hours duration.

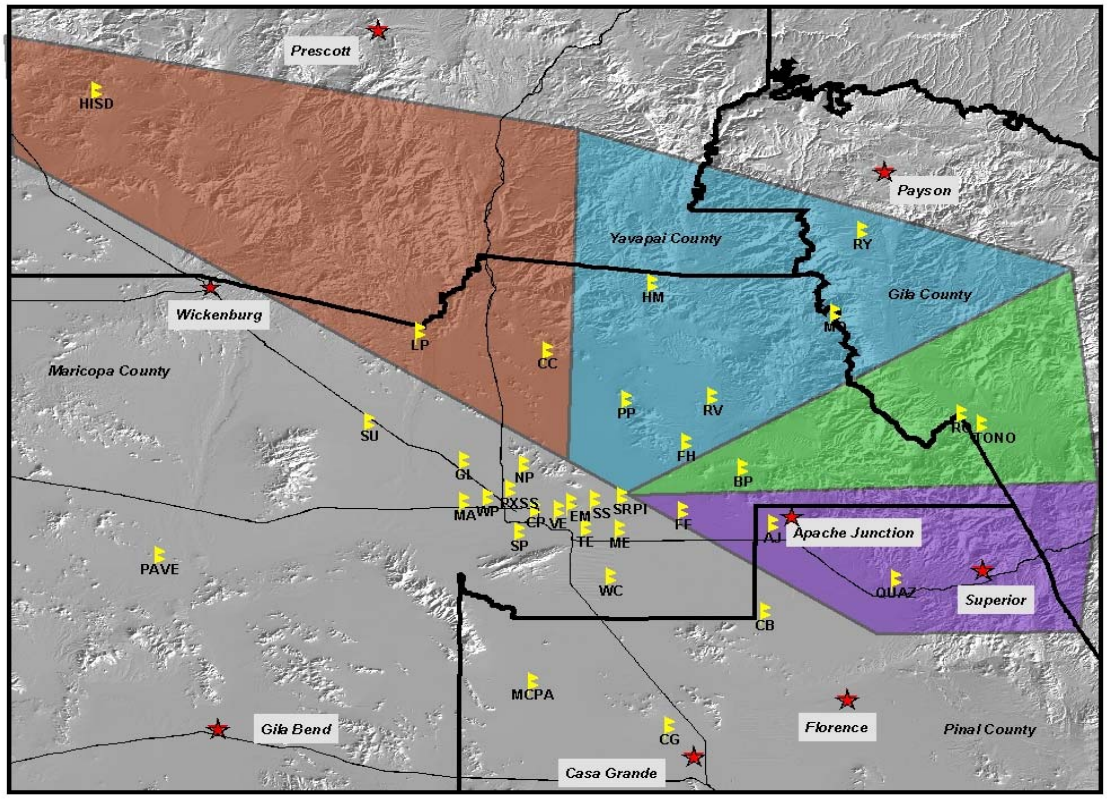
The few hours of drainage flow during the early daylight hours added to the early portion of the transitional winds, transported the urban plume toward the northwest under ozone formation conditions for three to ten hours on the episode days. The later part of the

transition period coupled with the upslope period pushed the plume into the mountainous northeast quadrant for periods of time ranging from eight to twelve hours. Wind speeds averaged five to ten MPH during the upslope period and were somewhat lighter during transition and drainage periods. These wind direction patterns were useful in interpreting the ozone measurements on these ozone episode days, and the persistence of wind in the different directions provided a sound basis for estimating the transport distance of the urban plume and the extent of geographic extent of ozone violations.

As previously mentioned, ozone concentration levels are well defined in the urbanized area by the relatively dense array of monitors. In the outlying areas there are large gaps between monitors which begs the question as to the extent of high ozone concentrations beyond the peripheral monitors which have recorded violations of the standard.

In consultation with ADEQ, a geographic area was identified that required further analysis to identify the portions that exceed the 80 and 85 ppb design criteria. The map in Figure 3 shows the area in question broken into four study sectors. The following section of this report describes how the boundary options for each sector were derived using the informational tools described above.

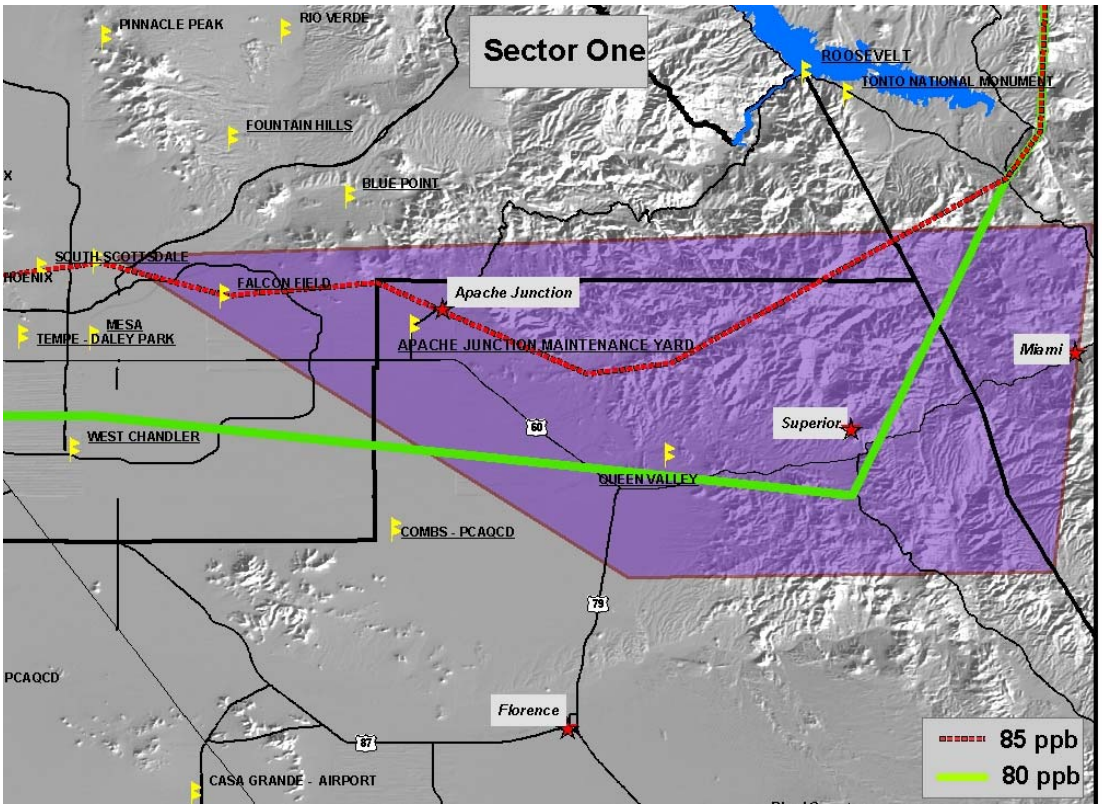
Figure 3. Map of Receptor Area Study Zones



Sources: ADEQ, USGS, ALRIS, Neuroth

Sector 1- This sector, shown in Figure 4, lies to the east of the Phoenix area mostly in Pinal County extends towards the town of Superior. There are three ozone monitors located in this sector: Falcon Field, Apache Junction, and Queen Valley. Ozone concentrations measured at Falcon Field and Apache Junction have been close to the standard. The Queen Valley monitor has only operated for two years with fourth high values of 79 and 83 ppb in 2001 and 2002, respectively. Ozone concentrations to the south of this sector in west Chandler and Pinal County have been below 80 ppb while measurements to the north have exceeded the standard.

Figure 4. Map of Receptor Area Study Zones – Sector 1



Sources: ADEQ, USGS, ALRIS, Neuroth

Prevailing upslope winds provides insight into the ozone pattern described above. Typical airflow during the critical ozone formation hours transports the urban plume mostly to the area north of this sector, the higher concentrations of ozone at Falcon Field and Apache Junction compared to measurements to the south indicate that the northerly portion of this sector is grazed by the transported urban plume.

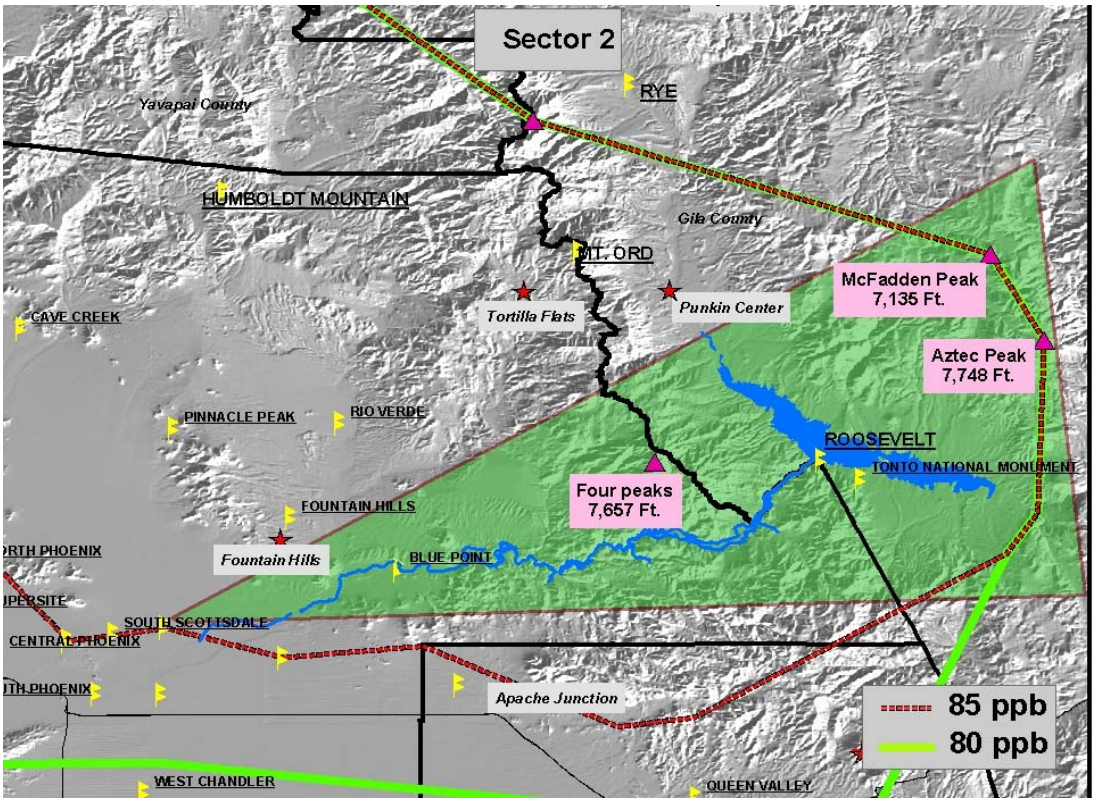
Modeling and monitoring data support the idea that the highest ozone concentrations in this sector occur in the elevated terrain in the north portion of this sector. Remote areas of the Superstition Mountains including elevations over 5000 feet, without the ozone

scavenging effect of fresh NO emissions almost certainly experience higher ozone than the Falcon Field and Apache Junction monitors which have recorded levels near the standard.

The boundary for the 80-ppb area is largely based on measurements at Tempe and Queen Valley and also on the expectation of higher concentrations in the remote portions of the sector. The 85-ppb boundary includes the Falcon Field monitor location and the northern portion of the Superstition Mountains nearest to Phoenix.

Sector 2- Figure 5 shows the location of this sector to the east-northeast of Phoenix, roughly centered on the Salt River valley to Roosevelt Lake and the Sierra Ancha Mountains, and the Mogollon Rim beyond.

Figure 5. Map of Receptor Area Study Zones – Sector 2



Sources: ADEQ, USGS, ALRIS, Neuroth

Two monitors are currently operated in this sector: Blue Point and Tonto. Both of these monitors are located at relatively low elevations in the Salt River valley. The Blue Point monitor, which is located about 28 miles east-northeast of Phoenix, has measured violations of the 8-hour ozone standard. The Tonto monitor located at Tonto National Monument near Roosevelt Lake is about 50 miles from Phoenix. The Tonto monitor has

only operated for one full ozone season and measured a fourth high concentration of 87 ppb in 2002. In 1997, an ozone monitor identified as Roosevelt operated near the location of the current Tonto monitor. The Roosevelt monitor measured a fourth high concentration of 84 ppb.

Much of the land in this sector is mountainous, with peaks above 7,000 feet. An ozone monitor was operated near the top of7,300-foot Mount Ord, located in the nearby portion of sector 3, from 1997 through 2001. Concentrations of ozone at Mount Ord exceeded the standard and this record was used to estimate high terrain impacts in sector 2. The use of Mount Ord monitor data for this sector is supported by the similarity in ozone measurements seen when comparing the Blue Point monitor measurements in sector 2 with corresponding measurements at the Fountain Hills monitor in sector 3. The Fountain Hills monitor is about the same distance from Phoenix and at a comparable elevation to Blue Point. It is also on the same trajectory for receipt of the Phoenix area plume as Mount Ord. The remarkably similar ozone concentrations at Blue Point and Fountain Hills can be seen on Table 1. The wind analysis for the nine ozone episode days also supports the conclusion that airflow from the urbanized area into sectors 2 and 3 are very similar.

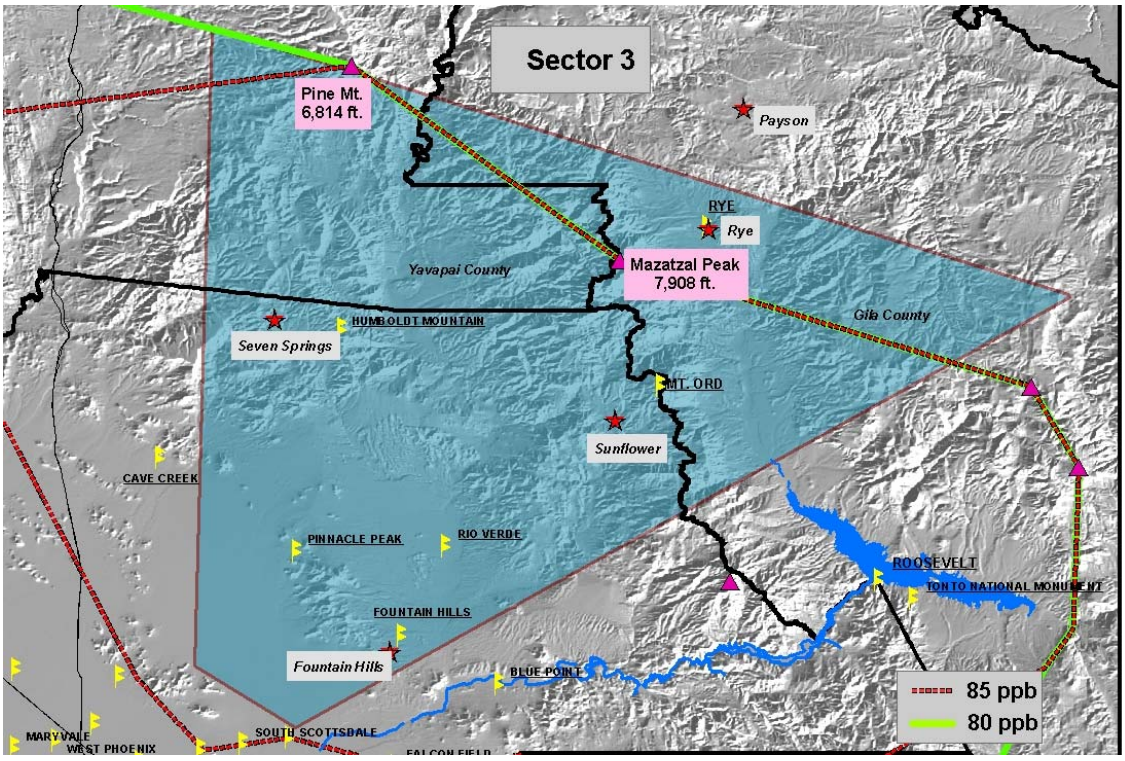
The 80- and 85-ppb boundaries shown on Figure 5, are virtually the same. Although concentrations above 80-ppb probably occur beyond the most distant portion of the boundary, there is no ambient record to guide a boundary line beyond that shown. It is concluded that the concentrations measured at Blue Point and Tonto indicate that concentrations of ozone, at or above the standard, occur throughout the Salt River valley at relatively low elevations. The high elevation areas around Four Peaks and in the Sierra Ancha Mountains are also considered to experience ozone violations based on the Mount Ord record as well as modeling predictions and the occurrence of transport winds from the Phoenix area into this area for up to twelve hours at velocities in the five to ten MPH range during hours of high ozone formation potential.

Sector 3- This sector, shown in Figure 6, is to the north-northeast of Phoenix, and is predominantly mountainous National Forest land. Three of the four ozone monitors that have operated in this sector have recorded concentrations above the standard. The Fountain Hills monitor referenced in the sector 2 discussion, is located in a residential area about 20 miles from Phoenix. The Mount Ord monitor, installed at about 7,300 feet, 50 miles northeast of Phoenix, was operated from 1997 until 2001, when it was discontinued due to difficulties with instrument access at the mountain-top location. The Humboldt Mountain monitor is located about 40 miles north-northeast of Phoenix at 4,900 feet. Both of these mountain monitors have measured 8-hour violations, and the Humboldt Mountain monitor recorded a network high 90 ppb in 2002. ADEQ operated an ozone monitor at the small town of Rye, located about 67 miles northeast of Phoenix at an elevation of 3,000 feet between 1997 and 1999. Ozone concentrations at this site were below 80 ppb.

The ozone violation level concentrations measured at Mount Ord and Humbolt Mountain, at distances of 50 and 40 miles from central Phoenix, and to a lesser extent, the 80-85 ppb

concentrations at the Hillside monitor located 80 miles northwest of Phoenix in sector 4, demonstrate the influence of the urban plume at high elevation locations, long distances from ozone producing emissions. The low ozone concentrations at Rye are thought to indicate that an ozone shadow occurs at low elevations leeward (downwind) of high terrain.

Figure 6. Map of Receptor Area Study Zones – Sector 3



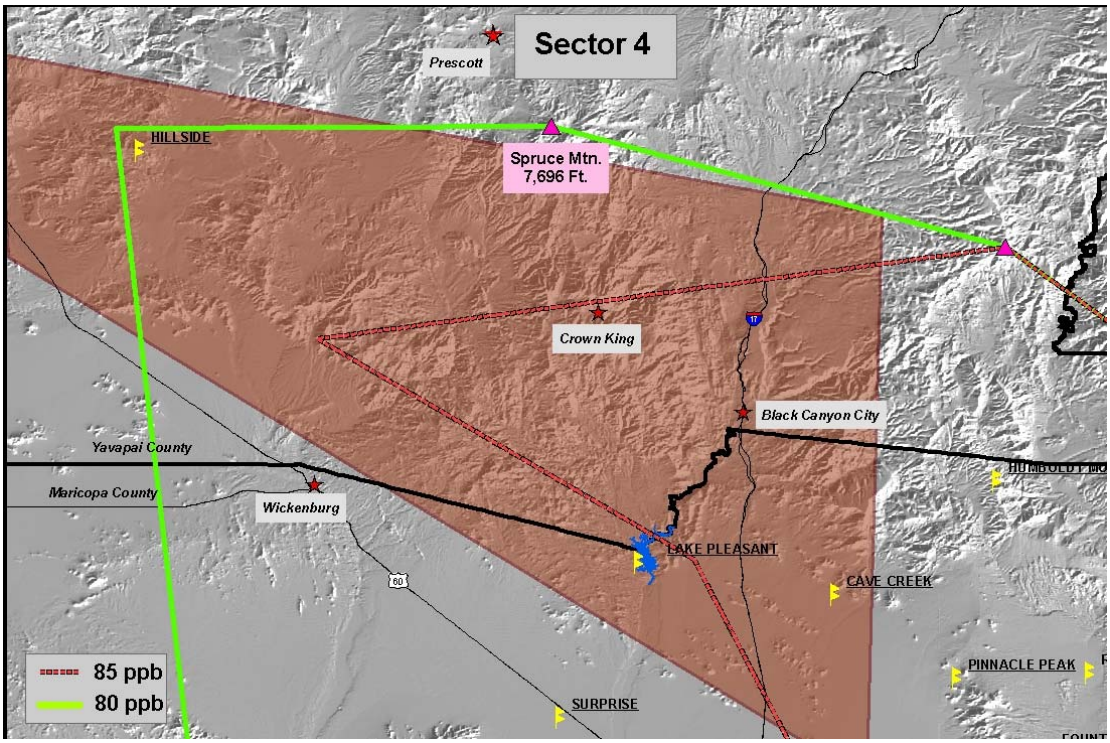
Sources: ADEQ, USGS, ALRIS, Neuroth

The 80- and 85-ppb boundary lines are virtually the same in this sector. Pine Mountain at 6,300 feet was chosen as the northernmost boundary limit. Pine Mountain is about 20 miles beyond Humboldt Mountain, along the same trajectory from Phoenix, and is about 1,800 feet higher. Modeling, wind persistence during ozone formation hours, and mountaintop ozone data, support the boundaries selected for this sector.

Sector 4- This sector, shown in Figure 7, is a large area to the north through northwest of Phoenix. Winds from the Phoenix area, during ozone formation hours, blow toward this direction during the final hours of drainage flow and continue during the transition to upslope. Three ozone monitors have operated in this sector, however only one has a lengthy record. The Hillside monitor, located about 80 miles northwest of Phoenix at an elevation of 5,000 feet, has operated since 1996. Fourth high ozone concentrations have been in the 80-83 ppb range, except in 2002 when a 89-ppb concentration was recorded. The Cave Creek monitor began operation in 2001, and has recorded fourth high values of

83 and 86 ppb in 2001 and 2002. An ozone monitor was operated at Lake Pleasant from 1998 to 2001 with concentrations averaging about 80 ppb.

Figure 7. Map of Receptor Area Study Zones – Sector 4



Sources: ADEQ, USGS, ALRIS, Neuroth

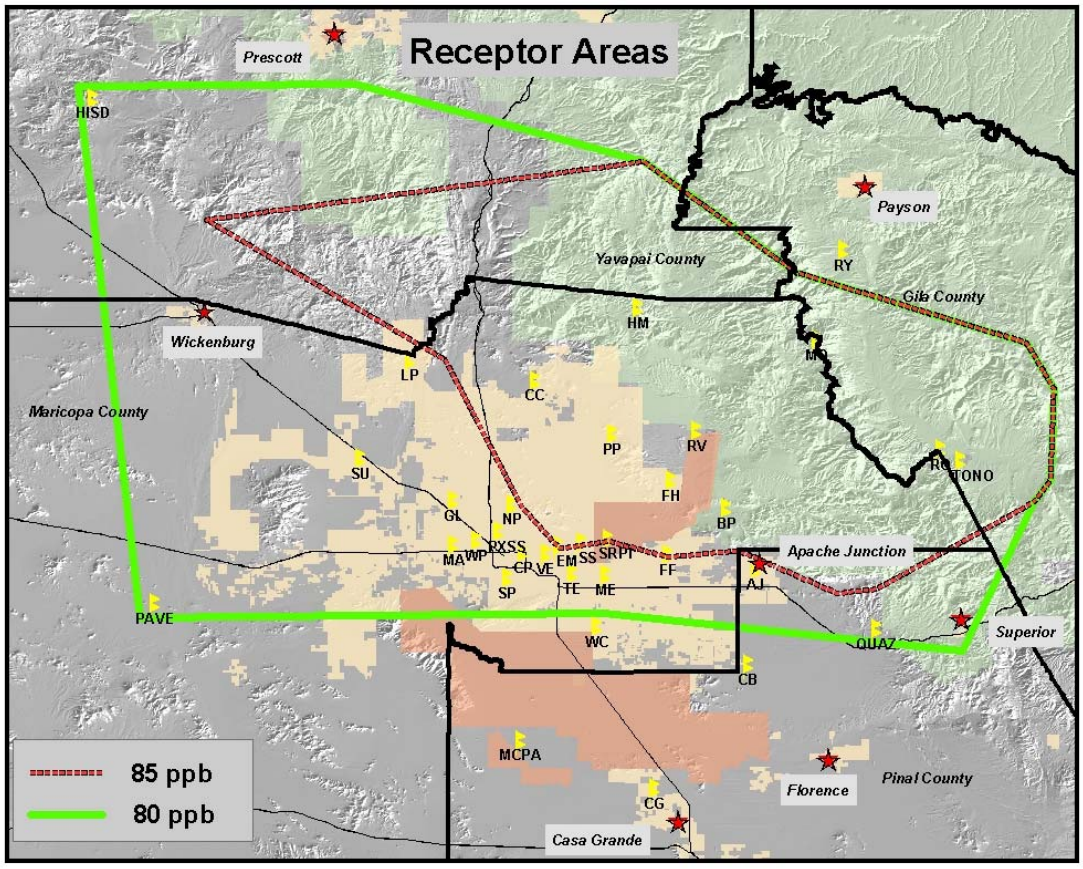
The higher ozone concentrations at Cave Creek compared to Lake Pleasant are expected because of the higher frequency and duration of winds from the south than from the southeast during ozone formation hours. The still higher ozone at the Humboldt Mountain monitor located just 4 miles east of this sector also reflect greater transport influence plus the lack of local emissions scavenging ozone. The ozone concentrations at Hillside at 5,000 feet and 80 miles from Phoenix suggest that concentrations on higher terrain along this trajectory and closer to Phoenix experience higher ozone concentrations. The high ozone history at Humboldt Mountain also lends credence to this idea.

Thus, it is concluded that emissions transported into this sector cause concentrations greater than 85 ppb in the Bradshaw and New River Mountains, to the north and north-northwest of the urbanized area, and the lower lying areas represented by the Cave Creek monitor. The larger 80-ppb boundary is drawn to include the Lake Pleasant and Hillside monitors locations. The western boundary line simply connects the northwest corner

anchored by the Hillside values with the Palo Verde monitor which is located south of sector 4, with measured ozone concentrations about 80 ppb.

The 80- and 85-ppb boundaries for the Receptor Study Area described above were extended into the urbanized area to complete the Receptor Area mapping. The 80- and 85-ppb boundaries in the urbanized area were drawn strictly to fit the actual measurements in this area. The completed maps with the combined rural and urban areas are shown in Figure 8.

Figure 8. Map of 80 and 85 ppb Receptor Area Boundaries



Sources: ADEQ, USGS, ALRIS, Neuroth